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Performance of Circular Footing with Vertical Reinforced Sand Bed Resting Adjacent to Sloping Ground

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Abstract: - In the present investigation, load intensity versus settlement behaviour of circular shaped footing on sloping sand layer without and with vertical reinforcement. Experiments were conducted and bearing capacity ratio were calculated at 25 mm settlement of footing. The influences of vertical reinforcement on load intensity were compared with unreinforced condition in dry and saturated state. To achieve above condition, slopping sand bed were prepared with relative density of 67% by using sand raining technique. The vertical reinforcement was placed at the edge of slopping ground and 10 mm away from the edge of footing and test were also conducted with U/B=0.625,1.250 and 1.875. In each U/B ratio test were conducted by varying number of reinforcement (N) that is N=1, 3, 5 and 7 and by varying inclination of reinforcement with horizontal at 30, 45, 60 and 90 degree. From the results it was found that 96.29 % improvement in bearing capacity ratio with U/B ratio 1.250 with five numbers of vertical reinforcement at 900 degrees compared with unreinforced condition in dry state. The marginal decrements in bearing capacity ratio of 40 % were noticed in saturated state.

Keywords: *Circular footing, Bearing Capacity Ratio, Sloping ground, Settlement, vertical reinforcement, Saturated state.*

1. Introduction

Now adays due to the scarcity of flat land, grounds with varying slopes are used for infrastructure development. In India the building construction activities along the sloping grounds of hilly areas in Western Ghats are facing foundation settlement and failures due to heavy rainfall. The footing resting on such a low bearing capacity soil exhibits large settlement problems under small loads. The improvement in strength properties of such soil required due to the scarcity of good sites and increase in infrastructure growth. Vidal (1969) first introduced the reinforcement elements in the foundations soil to enhance the bearing capacity and to avoid foundation settlement. The natural fibres, steel reinforcement, geotextile, geo-grids and composite materials used as reinforcement materials in footing foundations. The natural fibre like Bamboo was used as a reinforcement material in early studies. [1, 11].

In most of studies steel is used as a reinforcement in footing to enhance the bearing capacity of various types of footings [2, 3, 5]. The geotextiles are used in various sandy soils [7-8].

The geo-grids are used by various researchers [4, 6, 10]. The combined mining waste and reinforcement and composite materials like sand and fly ash are used in some of the case studies. The reinforced circular footing carries more loads compared to rectangle and square footings reinforced sand beds [9]. Hence to check the feasibility of location of footing near the edge of sloping land without and with vertical reinforcement under dry and on saturated conditions a circular footing model study is carried out. The Mild steel circular footing on sandy soil without and with reinforcement is used for study purposes under dry and on saturated conditions. The variation of Bearing Capacity Ratio during dry and saturated conditions of footing in sloping land was observed. During this study effective spacing of vertical reinforcement from the edge of the footing is checked.

2. Materials

The sand is collected from the nearby river side of Hassan city. The Sand is air dried and passed through 4.75mm IS sieve and relative density at 67% was maintained. We used the reinforcement with L/D equal to 90 mm. The aspect ratio remains constant for the entire experiment.

Tank size is decided from literatures survey. The soil beds were prepared in a test tank with inside dimensions of 250 x 250 x 375 mm and 40 mm diameter circular footing of 25 mm thickness. Tank has been prepared with a mild steel material with an aspect ratio of footing to the model is 4.5 and the sand raining technique is used to maintain the relative density at 67%.

The properties of sandy soil and specification of tank and footing were tabulated in Table 1.0 and Figure 1 respectively. From the Table.1.0 and Figure 1, it is found that the soil is poorly graded.

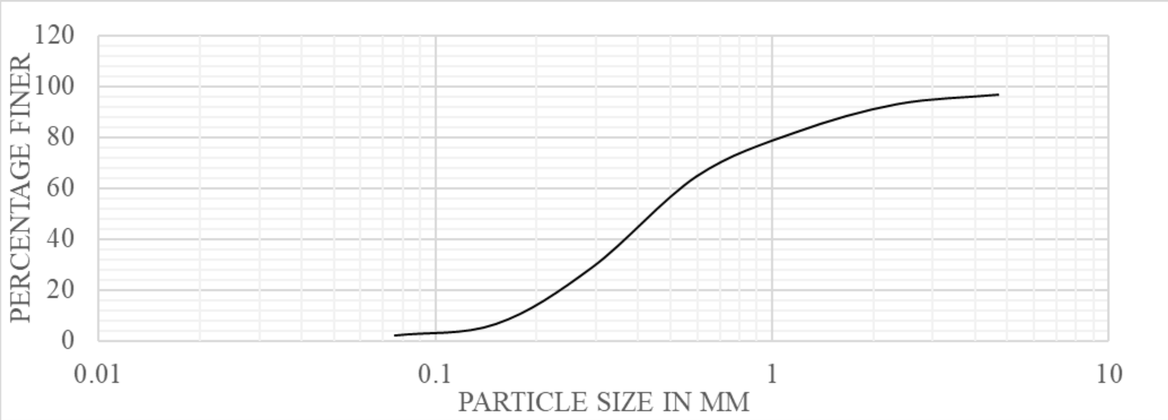

Figure 1 Particle size distribution of soil

Table 1. Basic properties of sand and reinforcing materials

Sl.no.	parameters	Results
1	Grain specific gravity	2.46
2	Compacting density of sand	Relative Density =67%.
3	Angle of friction	26^0
4	Angle of repose	45^0
5	Sieve analysis data	
	Co-efficient of uniformity Cu	12.5
	Co-efficient of curvature Cc	2.0
6	Bearing capacity of sand (Unreinforced sand) at failure	2.6 kN/m^2
7	Reinforcement type	Vertical steel reinforcement of 1 mm diameter
8	Model tank and footing is made up of MS Plate with specifications	Tank=Mild Steel plate(250mm*250mm*375mm) Footing= Mild Steel plate (40 mm circular footing with 25 mm thickness)
9	Model footing diameter to thickness ratio	1.6

3. Experimental setup and methodology

Experimental setup and methodology Circular Model footing test was conducted by preparing a sand bed with density of 15.2kN/m3 in a model tank having a size of 250 x 250 x 375 mm with circular footing of 40mm diameter surface footing category. The footing is loaded at a strain rate of 1.25mm/min for both unreinforced and vertical reinforcement for sloping sandy soil with varying U/B ratio 0.625 to 1.875. Figure 2 indicates the laboratory stimulation of sloping ground in dry state before and after failure. It has been found that after failure the sloping line shifted inward.

This inward shifting of sloping ground indicates that there is a slope failure with footing collapse. In order to avoid such problems vertical reinforcement is provided with the varying angle from the 10 mm away from the edge of sloping ground as shown in Figure 3. It has been found that after failure there will be bulging of partially saturated vertical sand bed without shifting of slopping ground inward. This clearly indicates that presence of reinforcement has prevented bulging of footing.

Figure 2 Effect of loading on surface footing resting on sloping ground before and after failure

Figure 3 Effect of loading on the 5 mm away from edge of footing with optimum reinforcement (before and after failure in a saturated sand bed)

4. Results and Discussions

4.1. Variation of bearing capacity ratio (BCR) with varying U/B ratio.

From *Figure 4* it is found that the load carrying capacity of sand at failure is2.6 kN/m^2. With vertical steel reinforcement of 1mm diameter bar below the center of the footing, the load carrying capacity of reinforced sand bed is increased to 3.25 kN/m^2. The percentage improvement of load carrying capacity of sand bed reinforced with central reinforcement on compared with unreinforced sand bed is 25% Similarly, for U/B ratio of 0.625, the load carrying capacity at failure for reinforced bed is 7 kN/m^2 and increase in bearing capacity is 169% on compared with unreinforced sand bed. For the same sand bed with reinforced spacing with U/B ratio of 1.250, the load carrying capacity at failure is 10kN/m^2 and increase in bearing capacity is 284.61%. For U/B ratio of 1.875, the load carrying capacity at failure is 6.95kN/m^2 and the increase in bearing capacity is 167.30%. From the analysis of increase in bearing capacity values, it has been found that there will be an improvement of bearing capacity value up to optimum with a reinforcement at 5cm from the edge of footing and U/B ratio of 1.250. This is because, the presence of reinforcement within the isobar will improves the friction between sand and the skin of reinforcement rather than presence of reinforcement beyond the isobar zone of influence. (Note= U/B ratio indicates the distance of location of vertical reinforcement from the edge of the slope and 10 mm away from the edge of footing towards slope)

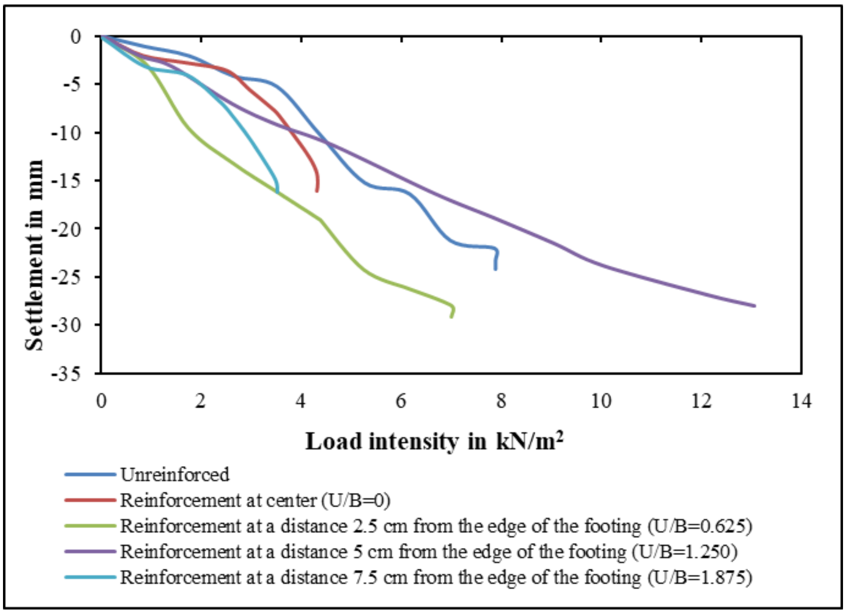

Figure 4 Load intensity v/s settlement curve of circular footing (U/B= 0.625,1.250 and 1.825, N=5 and orientation =90 degree)

4.2. Effect of number of reinforcements for optimal U/B ratio=1.250

From *Figure 5* it has been found that when the footing is placed at the 5 mm away from the edge of the footing, the load carrying capacity of sand at failure is 2.7 kN/m^2 and with vertical reinforcement at U/B of 1.250, the load carrying capacity at failure is 4.4 kN/m^2.The increase in bearing capacity at failure is 62.96%.To decide the optimum amount of the reinforcement, tests were carried out by varying numbers of bars at optimum U/B ratio of 1.250. By placing 7 numbers of the bars the increase in bearing capacity is 62.96%. Similarly, by placing 5 numbers of bars the load carrying capacity at failure is 5.3kN/m^2 and increase in bearing capacity 96.29%. When three numbers of bars placed the load carrying capacity at failure is 3.5kN/m^2 and bearing capacity is 29% and when one number of bar is placed the load carrying capacity at failure is 2.8 kN/m^2 and the increase in bearing capacity is 3.7%.

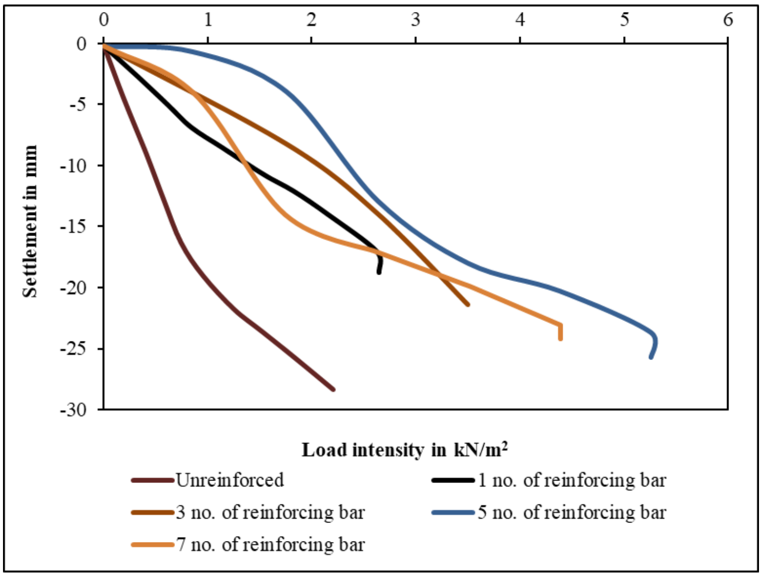

Figure 5 Load intensity v/s settlement curve of circular footing with varying vertical reinforcement. (U/B=1.250)

4.3. Effect of Inclination of reinforcement for optimal U/B ratio

In order to find out the angle at which the load carrying capacity will be maximum for the optimum U/B ratio and optimum numbers of bars when the footing is placed at the 10mm away from the edge of the footing. From *Figure 6* it was found that, when the reinforcement is placed at U/B ratio of 1.250 with 5 numbers of bars at an angle of 300,450, 600,900 and 1800 the load carrying capacity at failure are 4.4, 5.1, 5.0,5.3 and 2.6 kN/m^2.When reinforcement is placed at an angle 900, the load carrying capacity at failure is maximum. The percentage increase in bearing capacity variation ratio is 96.29%. From the above results it was observed that, the increase in load bearing capacity in sand bed with 5 numbers of vertical reinforcement placed at an angle 900 with U/B ratio of 1.250.

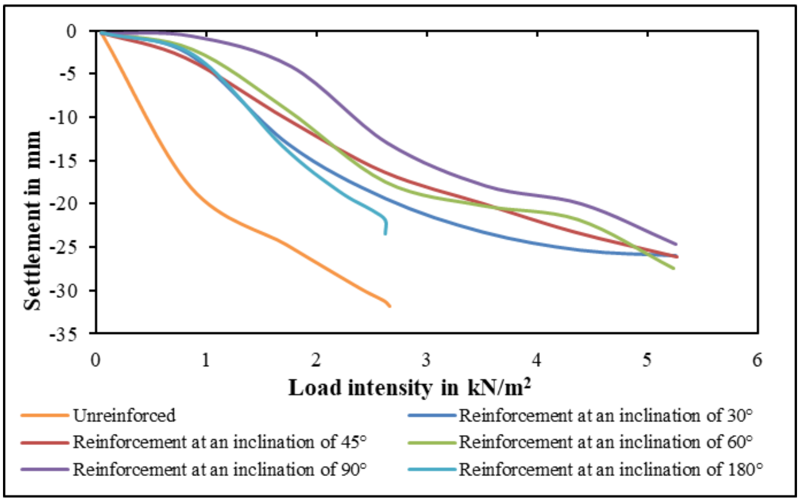

Figure 6 Load intensity v/s settlement behaviors for reinforced sand bed subjected to surface footing to find the optimum inclination of reinforcing bar at a distance (U/B=1.250) away from the slope of the embankment

4.4. Unreinforced sand flat bed in dry and fully saturated condition.

To know the behavior of the sand in fully saturated condition model footing test was conducted by preparing sand bed in fully saturated condition. The load was applied at constant rate of 1.25mm/min for unreinforced sand. From

Figure 7, it was found that the load carrying capacity at failure is 1.5kN/m 2 in saturation condition, whereas for unreinforced sand bed in dry condition, the load carrying capacity at failure is 2.6kN/m 2. It is found that, there is a decrease in the bearing capacity of 73.33% with saturation of the ground. From *Figure 7* it has been found that upon saturation of sand bed bearing capacity ratio of reinforced bed reduced by 40% on compared with unreinforced sand bed, this may be due to reduction of friction between reinforcement and the surrounding sand bed upon saturation.

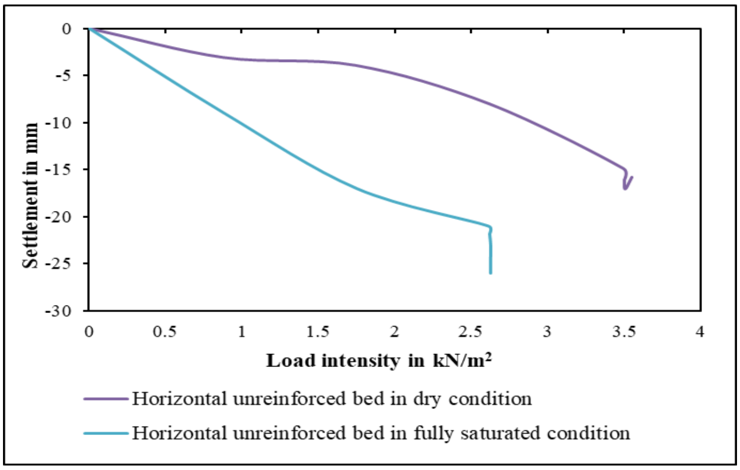

Figure 7 Load intensity v/s settlement behaviour for unreinforced sand bed in dry and fully saturated condition subjected to surface footing

4.5. Effect of Bearing Capacity Ratio for sand bed in a sloping ground reinforced with optimum distance and optimal number of reinforcement bars in dry and fully saturated condition

To know the behavior of the sand in fully saturated condition, model footing test was conducted by preparing sand bed in fully saturated condition. Experimental load was applied at constant rate of 1.25mm/min for reinforced sand in fully saturated condition. From the *Figure 8*, it was found that, the load carrying capacity of footing at failure for optimal reinforced sand bed within fully saturated condition is 2kN/m^2 whereas, for reinforced sand bed in dry condition the load carrying capacity at failure is 10 kN/m^2. On comparison with dry sand bed, in fully saturated sand bed bearing capacity at failure get reduces around 40%. This is due to the reduction of friction between sand and skin of reinforcement. To improve the Bearing Capacity under the saturated condition the surface of reinforcement is to be coated with bitumen layer.

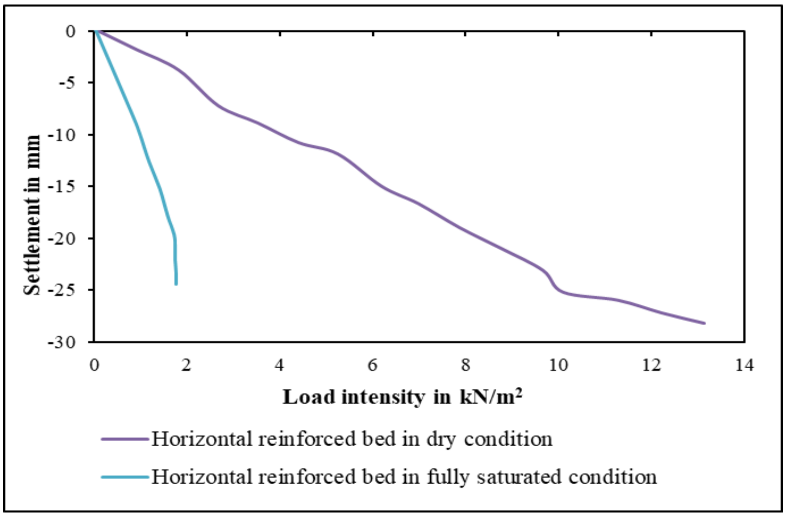

Figure 8 Load intensity v/s settlement behavior for reinforced sand bed in dry and fully saturated Condition subjected to surface footing.

5. Conclusion

Based on the experimental investigations carried out in the laboratory on circular footing resting on 10 mm away from the sand bed without and with reinforcement in dry and fully saturation condition, the following conclusions were drawn.

1. It has been observed that, reinforced sand bed carries more load at failure on compared with unreinforced sand bed.

2. It has been observed that 5 numbers of vertical reinforcement (1 mm diameter with 100 mm length of steel reinforcement) were placed below the footing in the sand bed with U/B ratio 1.250, there will be 96.29 percentage increase in the load carrying capacity of sand before failure. Hence U/B ratio 1.250 is found highest improvement in percentage in bearing capacity at failure on compared with unreinforced sand bed.

3. To know the orientation of reinforcement in the sand bed, the reinforcement was oriented with various inclinations with respect to horizontal sand bed. It has been found that 90^0 vertical reinforcements perform better than other orientations.

4. When sand bed is saturated unreinforced bed BCR reduced to 40 % as compared to the dry unreinforced sand bed.

5. In presence of saturated sand bed condition, the load carrying capacity of sand bed decreases. This is due to the reduction of friction between sand and skin of reinforcement.

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